Appendix G—Waupun Site Data

The hydrogeologic characterization of the Waupun site is based on data collected and interpreted by the USGS and USEPA. A total of 14 investigative methods were used at borehole FL-800, FL-801, and FL-802 (fig. 37) to develop the hydrogeologic framework for the Waupun site (table 1). Most of these methods contributed to the characterization.

Previous investigations

A comprehensive geologic and hydrologic study was performed in Fon du Lac County (Newport, 1962) in which the thickness, character, and areal extent of the various aquifers and confining units were determined. The Ordovician Sinnipee Group dolomites form the subcrop in the county, west of the Niagaran Escarpment, including the area beneath the Waupun site (fig. 36). In the eastern part of the county the Sinnipee Group is overlain by the younger rocks (Newport, 1962). Unconsolidated deposits overlie the Sinnipee Group wherever the Sinnipee is the subcrop. Where it constitutes the subcrop, the Sinnipee Group aquifer is unconfined and recharged primarily by the direct downward percolation of precipitation through unconsolidated deposits to the water table. As a result, the Sinnipee Group aquifer likely has been exposed to greater dissolution and infiltration at the Waupun site than in areas where overlying bedrock units are present. The general direction of ground-water flow in this area is to the southeast.

Core analysis

Bedrock core was cut in borehole FL-800 from 19.5 ft below ground surface (3-5 ft into competent bedrock) to a depth of 206 ft. Recovered bedrock core was described in detail (Mike Sargent, Illinois State Geological Survey, written commun., 1998)(table 21). The Glenwood Sandstone of the Ancell Group (fig. 11), the deepest unit encountered by the core, is a medium-grained, gray to brown sandstone. The Sinnipee Group at the site is about 185 ft thick and consists of light-gray to medium-bluish-gray dolomite. The unconsolidated deposits largely are of glacial origin. These deposits are about 16 ft thick, and consist of stratified till, clay, and sand and gravel.

The Sinnipee Group contains the Platteville Formation (Pecatonica, McGregor, and Quimbys Mill members), the Decorah Formation (Spechts Ferry Shale), and the Galena Dolomite (Dunleith and Wise Lake members) (table 21). The Platteville Formation is 51 ft thick and is composed of massive, crystalline dolomite. An unconformity appears to separate the Platteville Formation from the overlying Decorah Formation. The Decorah Formation is about 14 ft thick and composed of dolomite and shale. The dolomite:shale ratio of the Decorah Formation grades upward from 60:40 at the base to 95:5 at the top. The Galena Dolomite overlies the Decorah Formation and is about 119 ft thick in this area. The Galena Dolomite generally is an argillaceous dolomite. Shale partings and upward-fining sequences are common.

Physical analysis of the dolomite matrix was conducted on seven core samples of the Galena Dolomite, two samples of the Decorah Formation, and six samples of the Platteville Formation (table G1). Two samples of the Glenwood Formation also were analyzed. Among the Sinnipee Group samples, porosity values ranged from a low value of 1.6 percent at the top of the Galena Dolomite to a high value of 9.7 percent in the Decorah Formation. The mean porosity of the Decorah Formation samples is 8.3 percent, the mean porosity of the Galena Dolomite samples is about 2.4 percent, and the mean porosity of the Platteville Formation samples is 3.6 percent. The low porosity of the Galena Dolomite and Platteville Formation is consistent with the overall massive, crystalline nature of the dolomites in these units. There appears to be no appreciable difference in either the bulk or grain densities in samples of the three Sinnipee Group units. Grain density ranges from 2.5 to 2.9 g/cm^3 (table G1); the higher value is typical of pure dolomite (Hurlbut and Klein, 1977, p. 308).

Geophysical logs

Geophysical logs for boreholes FL-800, FL-801, and FL-802 indicate that the nature of the Sinnipee Group does not change appreciably over the relatively short distance (about 100 ft) between them (figs. G1, G2, G3).

Caliper

The caliper logs in all three boreholes indicate the borehole diameter is greater than its nominal value of 6 in. at about 810, 870, 881, 890, and 913 FANGVD29 (figs. G1, G2, G3). None of these features is greater than 1 in. in diameter, but they may correspond to secondary-permeability features and appear to correlate between each of the boreholes.

Natural Gamma

The high shale content of the Decorah Formation is reflected on the natural-gamma logs (figs. G1, G2, G3)

Table G1. Physical properties of selected rock core intervals from borehole FL-800 at the Waupun site, Fond du Lac County, Wis.

[NGVD of 1929, National Geodetic Vertical Datum of 1929]

Stratigraphy	Core interval, in feet above NGVD of 1929	Porosity, in percent	Bulk density, in grams per cubic centimeters	Grain density, in grams per cubic centimeters
Galena Dolomite	928.9 - 928.7	1.6	2.8	2.9
	906.7 - 907.3	1.9	2.4	2.5
	869.8 - 869.4	2.1	2.8	2.9
	852.3 - 852.0	3.2	2.8	2.9
	830.3 - 830.0	1.7	2.7	2.7
	825.7 - 825.4	3.8	2.7	2.8
	814.1 - 813.8	2.3	2.8	2.8
Decorah Formation	807.4 - 807.0	6.9	2.6	2.7
	799.4 - 799.0	9.7	2.5	2.8
Platteville Formation	794.6 - 794.3	1.8	2.8	2.8
	786.0 - 785.7	3.7	2.7	2.8
	774.8 - 771.5	4.0	2.7	2.8
	765.8 - 765.0	4.3	2.7	2.8
	755.1 - 754.8	4.1	2.7	2.8
	747.8 - 747.5	3.7	2.7	2.8
Glenwood Formation	747.2 - 746.7	3.0	2.7	2.8
	744.9 - 744.6	14.6	2.3	2.6

as a zone of higher gamma counts per second between about 796 and 810 FANGVD29 (geophysical log altitudes appear to be about 2 ft lower than correlative core altitudes). The more massive, less argillaceous, Galena Dolomite and Platteville Formation both have lower gamma cps than the Decorah Formation.

Normal Resistivity

Normal resisitivity logs were run to aid stratigraphic correlation at the Waupun site. The shaley nature of the Decorah Formation is reflected in lower resistance on the short-normal resistivity log (figs. G1, G2, G3). Short-normal resistivity logs indicated no clear response to areas of potential secondary-permeability features identified with the caliper logs.

Neutron

Neutron logging was performed only in borehole FL-800. The following discussion is a summary of logging results provided by Fred Paillet (U.S. Geological Survey, written commun., 1997). The neutron log (calibrated for limestone porosity) shows values of –4 to –2 percent over all of borehole FL-800 except for the Decorah Formation at 796-810 FANGVD29, with an apparent porosity of 10-20 percent. The higher porosity of the Decorah Formation in comparison to the rest of the Sinnipee Group (table G1) is reflected in the neutron porosity log (fig. G1). Neutron-porosity logs calibrated in limestone need to be corrected to account for the effects of quartz lithology in a sandstone. The difference in mineral grain lithology causes a limestone-calibrated, neutron-porosity log to read –5 percent in a 100 percent quartz environment, whereas all neutron-porosity calibrations should tend toward the same value in 100-percent water. Thus, a +5 percent porosity calibration correction is required to convert limestone-calibrated porosity to quartz-calibrated porosity in the vicinity of the zero-porosity limit on the neutron log. The correlation decreases linearly with increasing porosity. The small negative values for porosity, from –4 to 0 percent, probably indicate the substantial portion of quartz (possible chert) in the dolomite. The highest apparent porosity measured with the neutron log at borehole FL-800 is associated with an increase in borehole diameter at the top of the Decorah Formation at about 810 FANGVD29. It is unclear if this increased porosity is associated with the shale layer or the possible fracture.

Acoustic Televiewer

The following discussion is a summary of logging results provided by Fred Paillet (U.S Geological

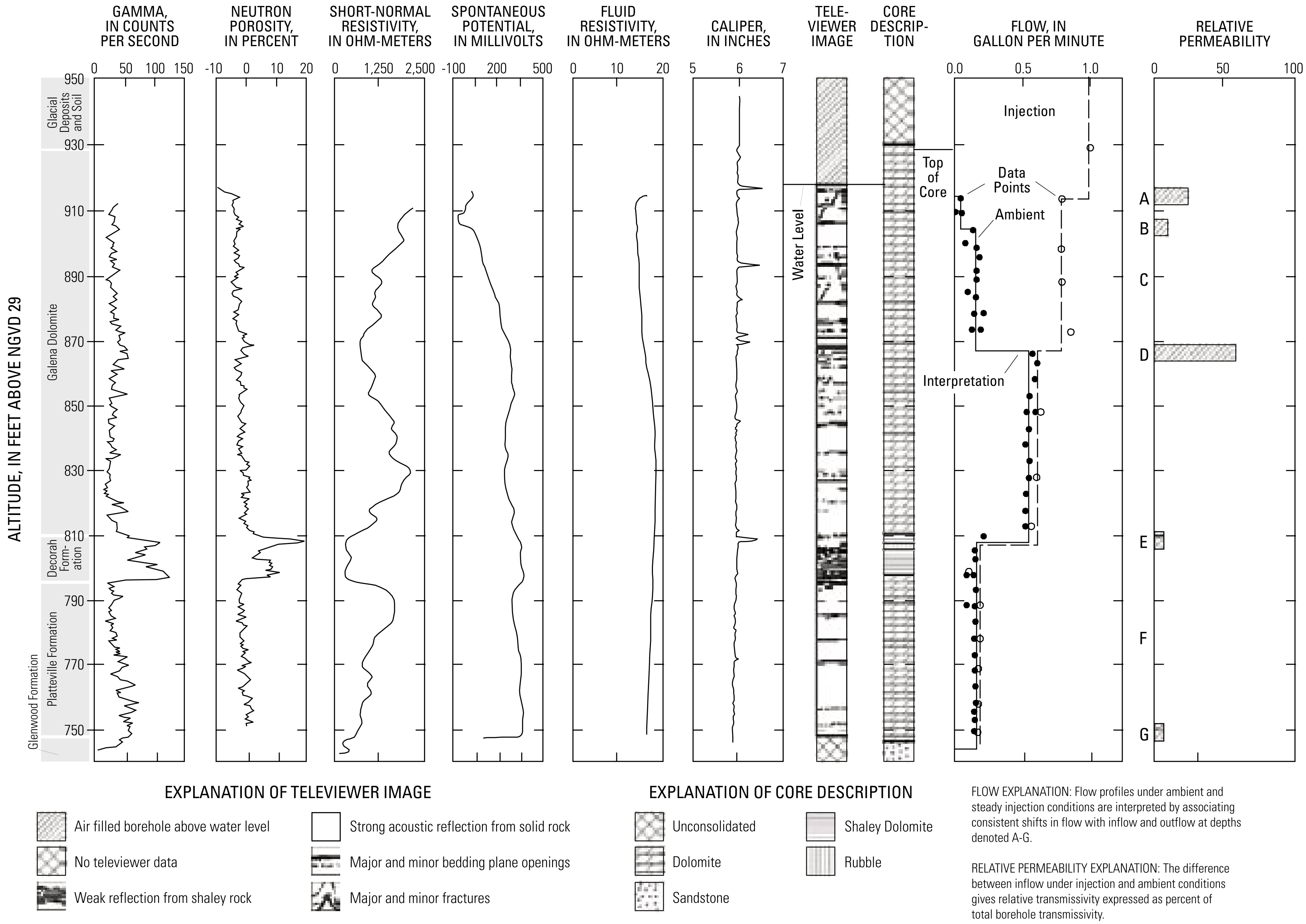

Figure G1. Geophysical logs, televiewer image, generalized core description, heat-pulse flowmeter data and relative permeability plot for borehole FL-800 at the Waupun site, Fond du Lac County, Wis.

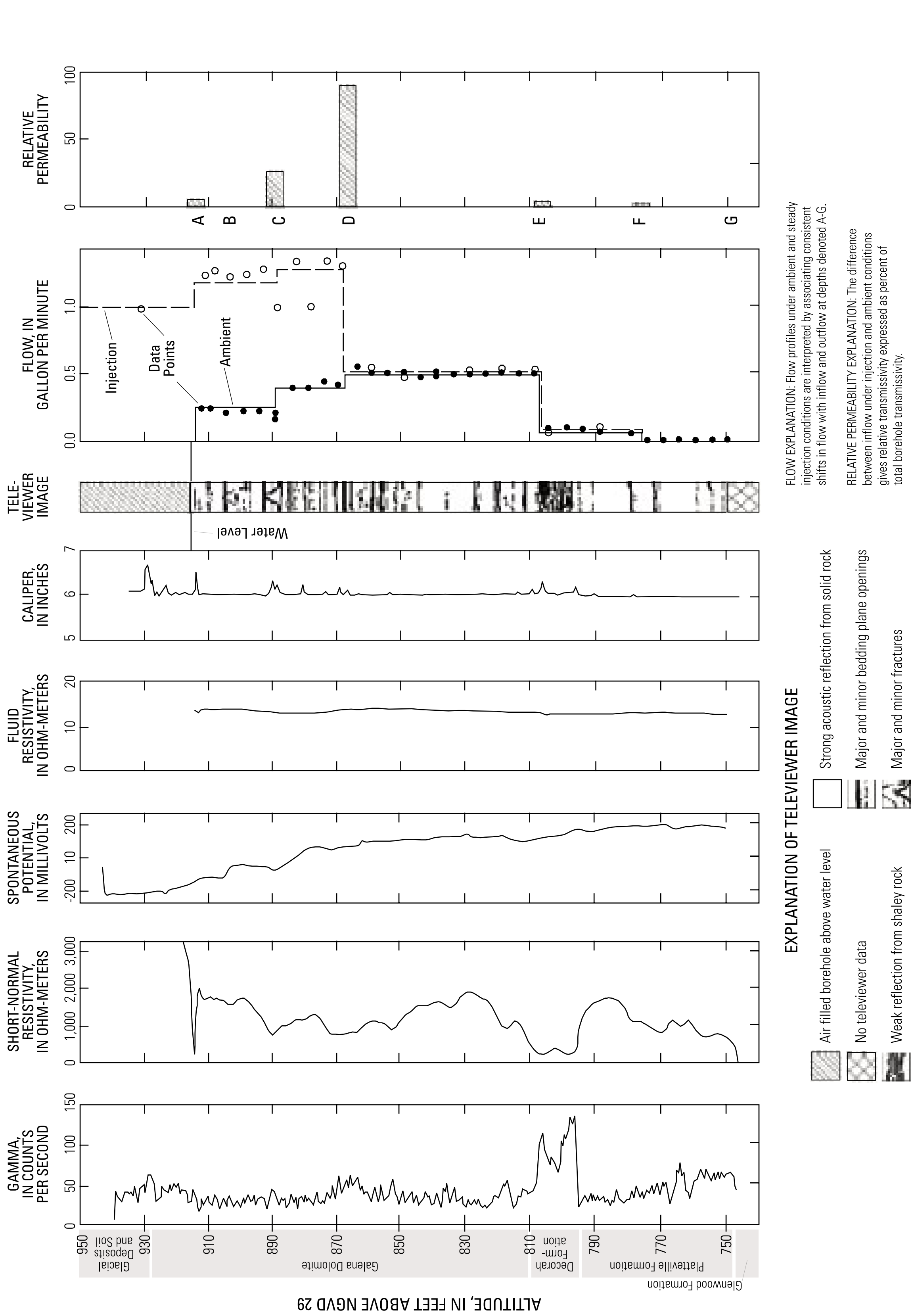

Figure G2. Geophysical logs, televiewer image, heat-pulse flowmeter data and relative permeability plot for borehole FL-801 at the Waupun site, Fond du Lac County, Wis.

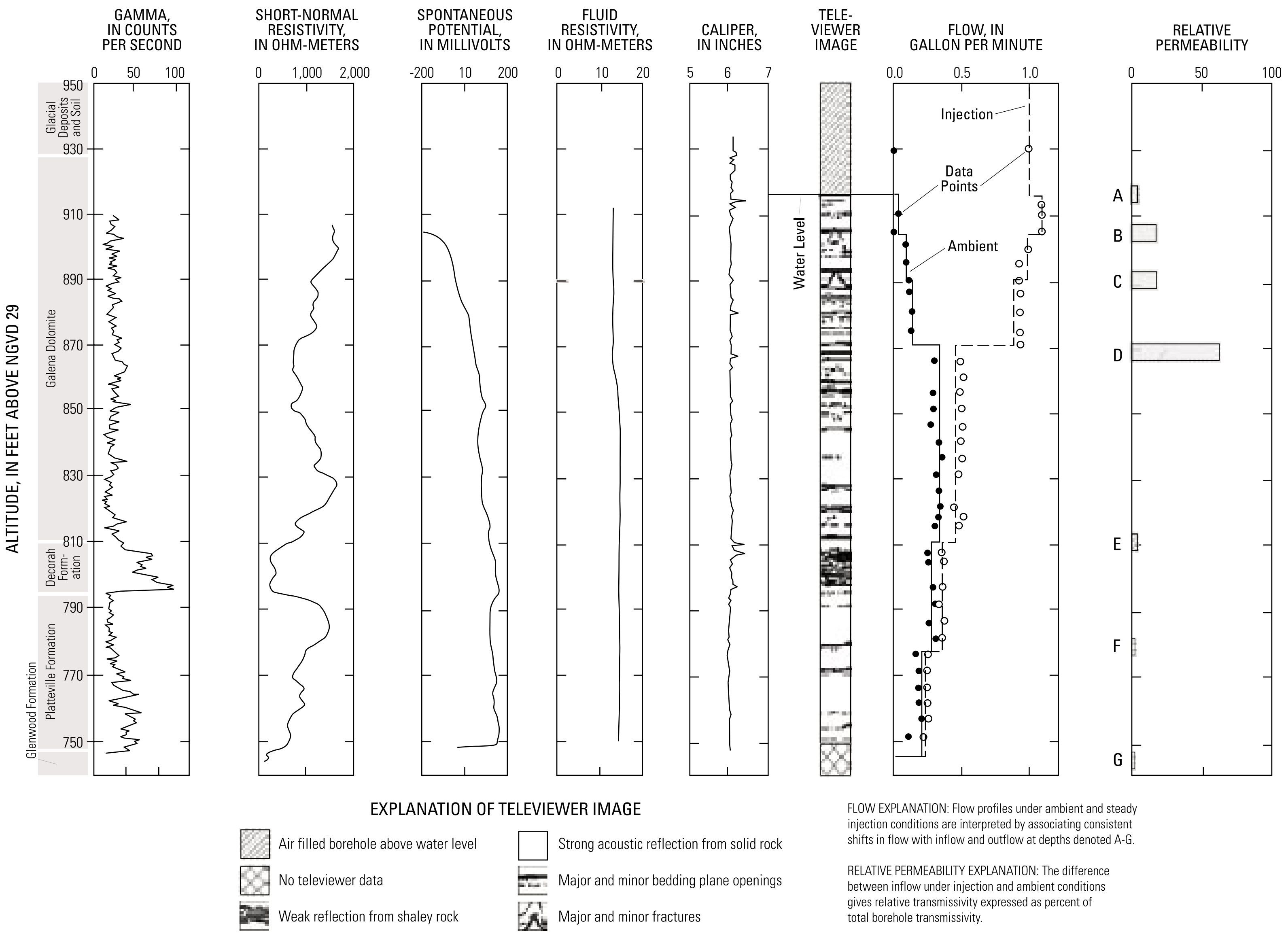

Figure G3. Geophysical logs, televiewer image, heat-pulse flowmeter data and relative permeability plot for borehole FL-802 at the Waupun site, Fond du Lac County, Wis.

Survey, written commun., 1997). The televiewer logs indicate many horizontal bedding-plane partings at each of the boreholes, most of which correspond to areas of increased borehole diameter identified with the caliper logs. The water level at about 915 FANGVD29 coincides with a prominent bedding-plane parting identified with the caliper logs that could not be imaged with the televiewer because the televiewer only transmits a signal in a fluid filled borehole. The distribution of bedding-plane partings on the televiewer logs does not correlate with the distribution of bedding-plane partings described in the core, probably because the listing of bedding-plane partings in the core description does not indicate that some partings apparently are much bigger or more extensively weathered than others. The televiewer log shows a massive interval at 900-907 FANGVD29, which correlates with a massive interval in the core. However, there is a conspicuous bedding plane at 913 FANGVD29 on the televiewer log that is not referred to in the core description.

Two inclined fractures (at 910 and 888 FANGVD29) are indicated on the televiewer log for borehole FL-800 and detected on the core (fig. G1). A third fracture indicated by the core near 874 FANGVD29 was not indicated in the televiewer log. A large inclined fracture was detected with the televiewer log at 890 and 900 FANGVD29 in borehole FL-801. All of these fractures dip to the ENE and strike to the WNW.

Borehole GPR

A single-hole directional borehole GPR survey was conducted in FL-800 using a 60-MHz transmitter and a 60-MHz directional receiver. The results of the analysis of the single-hole directional reflection survey in FL-800 indicate that a group of reflectors at the site have strikes from magnetic north of 40 degrees to 60 degrees, with a conjugate set of 130 to 150 degrees (table G2) (John Lane, U.S. Geological Survey, written commun., 1997). Other strikes are interpreted from the data at 190 and 300 degrees. Reflector dip data are presented as angles with respect to the borehole. These data must be subtracted from 90 degrees to obtain dip. Some reflectors correlate well with other borehole-geophysical logs, and others do not correlate. A partial explanation for any lack of correlation may be that the borehole radar can obtain reflections from structures that are present beyond the borehole but do not extend to the borehole wall. The interpretations include a "depth of intersection" for each reflector; this value is the depth at which the reflector would intersect the borehole if it were large or areally extensive enough to do so. In some cases, the intersection depth can be negative, or it can project to depths deeper than the drilled borehole depth. These depths are "tie-points" that allow one to reconstruct the geometry and location of the reflectors with respect to the borehole (John Lane, U.S. Geological Survey, written commun., 1997).

A cross-hole radar tomography survey was conducted between boreholes FL-800 and FL-802 using a 22-MHz transmitter and receiver. The cross-hole tomography data were interpreted to produce velocity and attenuation tomograms between FL-802 (left-side tomogram) and FL-800 (John Lane, U.S. Geological Survey, written commun., 1997) (figs. G4, G5). The velocity tomograms show the lowest velocities between 817 and 785 FANGVD29. The attenuation tomograms indicate the highest attenuation centered at about 802 FANGVD29. The decrease in radar-propagation velocity and the increase in radar-wave attenuation have been associated with increased water content and EM-wave attenuation associated with high-porosity, electrically conductive rocks. The low velocity/high-attenuation zone correlates well with a zone of decreased resistivity and increased porosity and gamma counts from about 795 to 810 FANGVD29, as indicated on the short-normal resistivity, neutron porosity, and natural-gamma logs. This zone has been interpreted as a shaley dolomite (Decorah Dolomite). The low-velocity/high-attenuation zone, extending between FL-802 and FL-800 in the velocity and attenuation tomograms at about 810 FANGVD29, is consistent with the interpretation of a fracture at this depth made with the other borehole-geo-

Table G2. Results of analysis of the single-hole directional reflection survey in borehole FL-800, Waupun site, Fond du Lac County, Wis.

[NGVD of 1929, National Geodetic Vertical Datum of 1929; na, not applicable]

Altitude (feet above NGVD of 1929)	Angle (degrees)	Strike (degrees from magnetic north)	Dip (degrees from horizontal)
3,696	1.1	40	88.9
1,019	5.6	130	84.4
970	14.5	na	75.5
933	61.7	na	28.3
925	61.6	60	28.4
922	29.2	10	60.8
916	90.0	na	.0
907	90.0	na	.0
870	Subhorizontal	150	Subhorizontal
853	88.4	na	1.6
848	90.0	300	.0
816	75.5	na	14.5
805	90.0	na	.0
797	90.0	na	.0
745	66.5	na	23.5

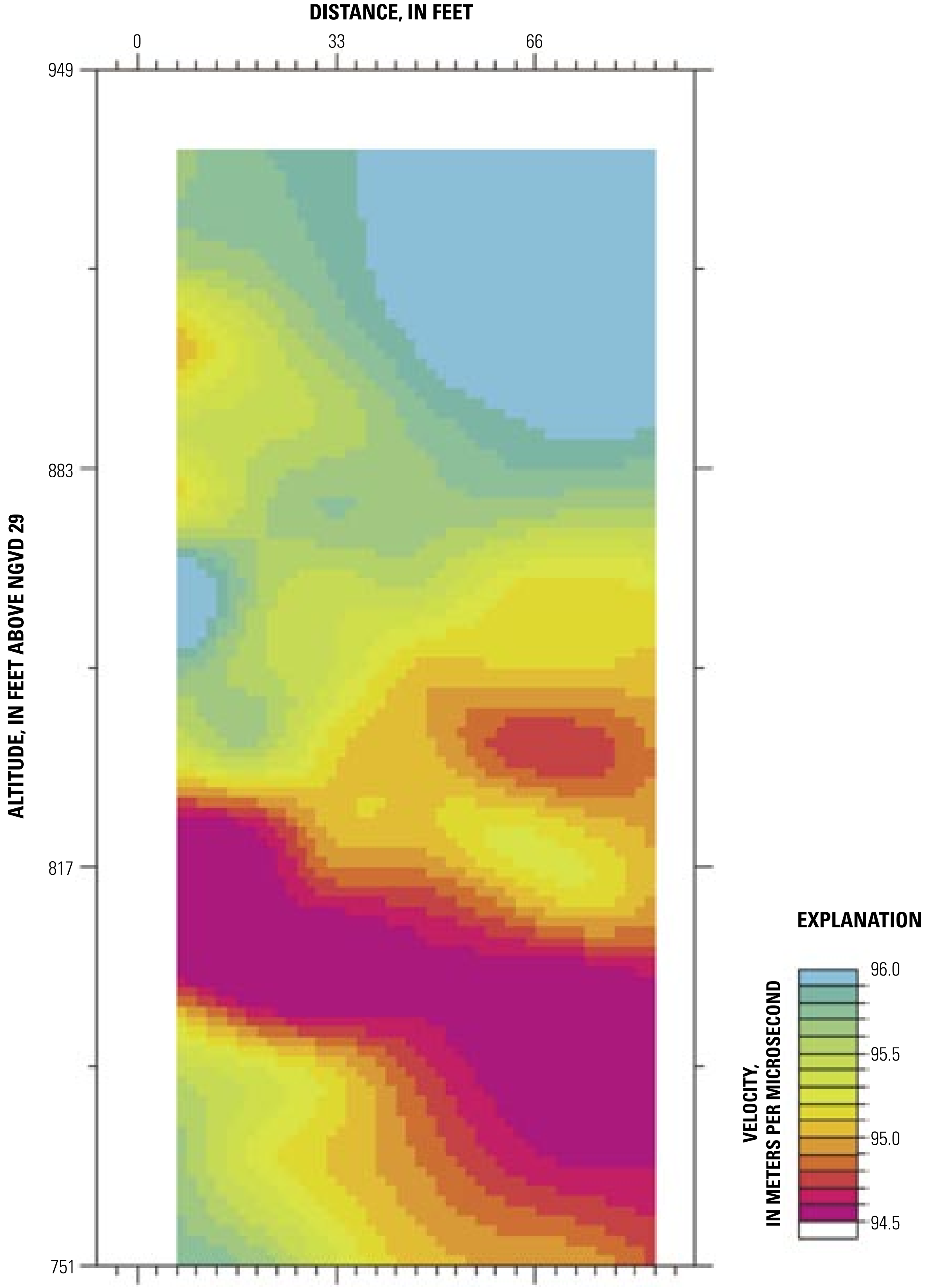

Figure G4. Cross-hole velocity tomogram between boreholes FL-800 and FL-802, Waupun site, Wis.

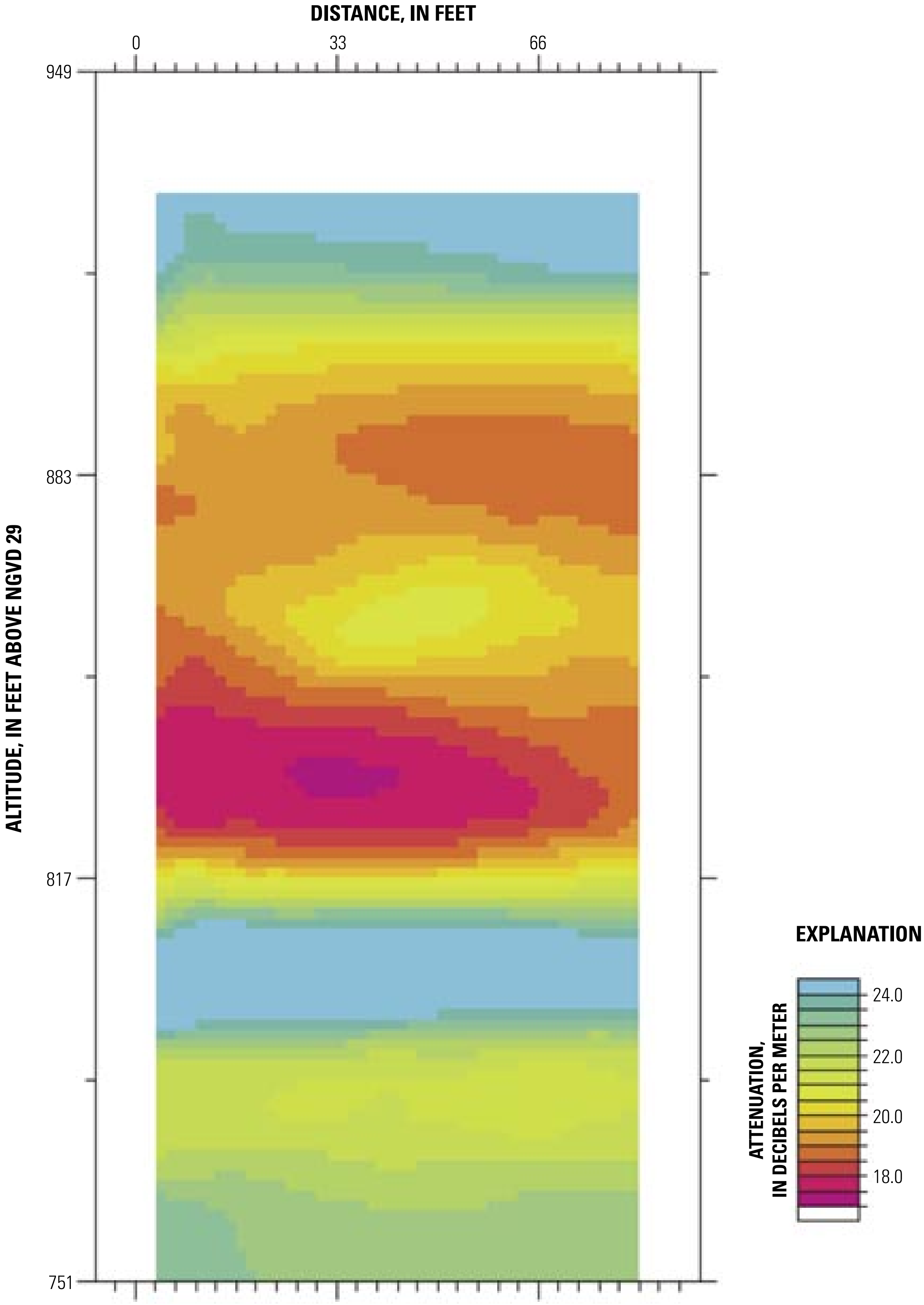

Figure G5. Cross-hole attenuation tomogram between boreholes FL-800 and FL-802, Waupun site, Wis.

physical logs in boreholes FL-800 and FL-802. This zone is near the upper contact of the shaley dolomite and the “cleaner” dolomite.

Hydrology

Water-level measurements, geophysical logging, and aquifer testing were used to assess the hydrology of the Sinnepee Group aquifer at the Waupun site.

Water-level measurements

Water levels were measured once in nine test intervals isolated by use of a packer assembly in borehole FL-800 and two intervals in each of boreholes FL-801 and FL-802 (fig. G6). Static water levels were measured in the selected intervals (table G3), and vertical hydraulic gradients were estimated by comparing levels in adjacent intervals (table G4). Vertical hydraulic gradients were found to be almost uniformly down, with values ranging from 0.040 to 0.863 ft/ft. The few upward gradients were found to range from 0.006 to 0.797 ft/ft. The gradients measured in intervals K and J are 0.062 ft/ft down in borehole FL-800, 0.058 ft/ft down in borehole FL-801 and 0.057 ft/ft down in borehole FL-802 (table G4).

Geophysical logs

Fluid Resistivity

Fluid resistivity indicates a slight but consistent increase at about 870 FANGVD29 in all three boreholes (figs. G1, G2, G3). Fluid resistivity also shows a slight decrease at about 807 FANGVD29 in borehole FL-801 and a slight decrease beginning between about 810 and 820 FANGVD29 in borehole FL-800. These intervals may correspond to the location of permeable features in the Galena-Platteville aquifer.

Flowmeter Logging

The following discussion is from a summary of logging results provided by Fred Paillet (U.S. Geological Survey, written commun., 1997). Flowmeter logging under ambient conditions identified 0.2-0.8 gal/min of downward flow in each of the boreholes. The flowmeter profiles indicate that the flow enters and exits at bedding-plane partings at about 810 and 870 FANGVD29 in each of the boreholes, with flow at about 890 FANGVD29 in boreholes FL-801 and FL-802, and about 905 FANGVD29 in boreholes FL-800 and FL-802. There also is inflow from one or more features above or near the water level (about 915 FANGVD29) in each of the boreholes, possibly the fracture identified with the caliper log at about 915 FANGVD29. Each of these features appears to be permeable. Although the same general set of bedding planes seems to be active in all three boreholes, including one associated with the top of the Decorah Formation at about 810 FANGVD29, the amount contributed from each parting varies between boreholes.

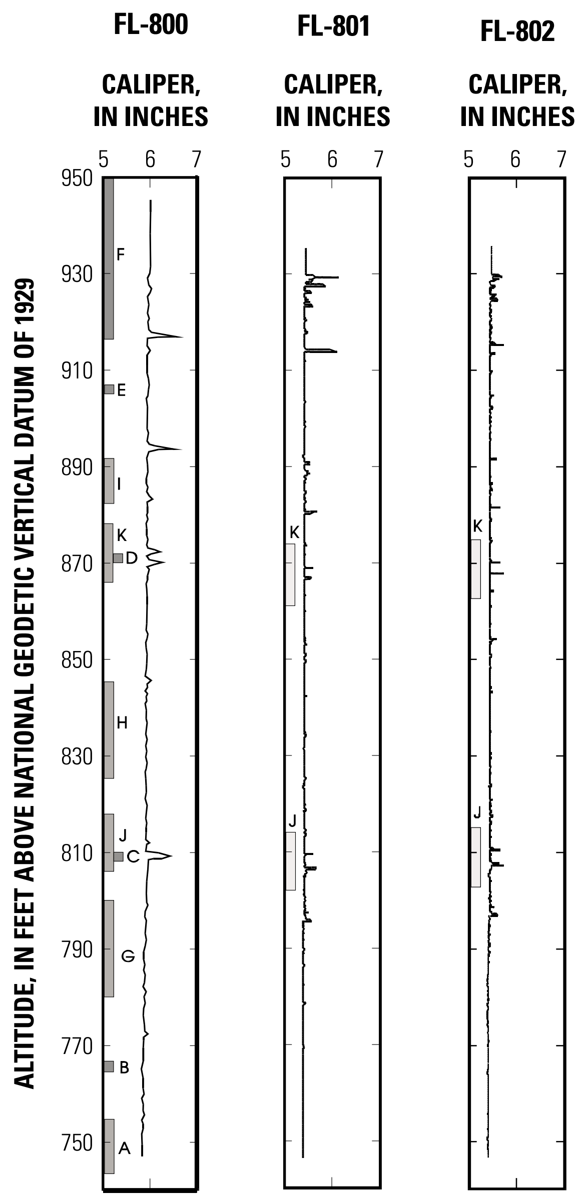

Figure G6. Caliper logs, packed intervals and test-interval designation for boreholes FL-800, FL-801, and FL-802, Waupun site, Wis.

Table G3. Measured static water levels in test intervals isolated with a packer assembly in boreholes FL-800, FL-801, and FL-802 at the Waupun site, Fond du Lac County, Wis.

[NGVD of 1929, National Geodetic Vertical Datum of 1929]

Borehole name	Test interval	Altitude of test interval, in feet above NGVD of 1929	Stratigraphy	Water level altitude in test interval, in feet above NGVD of 1929
FL-800	F	917 - 930.5	Galena Dolomite-Wise Lake and Dunleith Dolomite members	922.45
	E	907 - 905	Galena Dolomite-Wise Lake and Dunleith Dolomite members	915.47
	I	892 - 882.1	Galena Dolomite-Wise Lake and Dunleith Dolomite members	914.71
	D	872 - 870	Galena Dolomite-Wise Lake and Dunleith Dolomite members	914.80
	K	877.4 - 865.9	Galena Dolomite-Wise Lake and Dunleith Dolomite members	911.34
	H	844 – 824.1	Galena Dolomite-Wise Lake and Dunleith Dolomite members	912.15
	C	810 - 808	Decorah Formation-Spechts Ferry Shale	912.70
	J	817.4 – 805.9	Galena Dolomite-Wise Lake and Dunleith Dolomite members, and Decorah Formation-Spechts Ferry Shale	907.63
	G	800 – 780.1	Platteville Formation-Quimbys Mill member	889.00
	B	768 - 765	Platteville Formation-McGregor member	908.16
	A	755 - 744	Platteville Formation-Pecatonica member and Ancell Group-Glenwood Formation	896.22
FL-801	K	873.5 - 861.8	Galena Dolomite-Wise Lake and Dunleith Dolomite members	909.32
	J	813.5 – 801.8	Galena Dolomite-Wise Lake and Dunleith Dolomite members, and Decorah Formation-Spechts Ferry Shale	905.84
FL-802	K	874.5 - 863	Galena Dolomite-Wise Lake and Dunleith Dolomite members	911.22
	J	814.5 - 803	Galena Dolomite-Wise Lake and Dunleith Dolomite members, and Decorah Formation-Spechts Ferry Shale	907.80

The relative amounts of water entering and exiting a borehole depends on the product of fracture permeability and the head difference driving the flow. A true relative permeability profile can be obtained by subtracting inflows obtained under two different hydraulic conditions. Ambient and steady injection conditions are described here. The data are plotted as discrete flowmeter measurements (data) and as "step profiles" (the interpretation) (figs. G1, G2, G3). The differences profiles show that the pair of bedding-plane fractures at about 870 FANGVD29 may be much more permeable than any of the other bedding planes intersecting the borehole. The bedding plane at about 915 FANGVD29 is not fully saturated, so these data may not be a fair representation of the relative permeability of that bedding plane.

The data do not allow comparison of the relative permeability of the fractures between boreholes. In order to do this comparison, the relative flows must be normalized. Normalization is done by measuring the drawdown (here build-up) produced by the pumping (here injection) (figs. G1, G2, G3). The boreholes were so productive that no change in water levels was measured during injection and the data could not be normalized to compare relative permeability across the boreholes.

The logs from all three boreholes correlate closely. The bedding planes conducting flow are similar for all three boreholes. However, there is some difference in the relative amounts of flow in each borehole, which indicates the variability of the bedding-plane permeability. The results indicate that the bedding-plane partings at about 868-870 FANGVD29 are the main conduit. The bedding-plane parting at about 915 FANGVD29 also clearly is important as it appreciably affects water levels.

Aquifer tests

Slug tests and constant-discharge aquifer tests were performed at the Waupun site. Both types of aquifer tests improved the understanding of the hydrology of the secondary-permeability network at the site.

Slug tests

Based on inspection of the core and results of the geophysical logging, slug tests were conducted on nine selected test intervals isolated with a packer assembly in borehole FL-800 and two intervals in each of boreholes FL-801 and FL-802 (fig. G6). These intervals were chosen to evaluate the range of Kh present in both fractured and unfractured parts of the boreholes. Estimated Kh values ranged from 0.002 to 117 ft/d (table G5). Test intervals that included bedding-plane partings had estimated Kh values ranging from 0.2 to 177 ft/d. Test intervals that did not contain bedding-plane partings had estimated Kh values ranging from 0.002 to 1 ft/d. Perme-

Table G4. Vertical hydraulic gradients calculated between selected test intervals isolated with a packer assembly in boreholes FL-800, FL-801, FL-802 at the Waupun site, Fond du Lac County, Wis.

[-, denotes downward flow]

Borehole name	Test intervals being compared	Vertical hydraulic gradient, in foot per foot
FL-800	F/E	-0.393
	E/I	-.040
	I/D	.006
	I/K	-.219
	D/H	-.073
	K/H	.020
	K/J	-.062
	H/C	.024
	H/J	-.200
	C/G	-1.251
	J/G	-.863
	G/B	.797
	B/A	-.724
FL-801	K/J	-.058
FL-802	K/J	-.057

Table G5. Horizontal hydraulic conductivity of test intervals isolated with a packer assembly in boreholes FL-800, FL-801, and, FL-802 estimated from slug tests at the Waupun site, Fond du Lac County, Wis.

[NGVD of 1929, National Geodetic Vertical Datum of 1929]

Borehole name	Test interval	Altitude of test interval, (feet above NGVD of 1929)	Horizontal hydraulic conductivity, (feet per day)
FL-800	F	917 - 930.5	0.2
	E	907 - 905	1
	I	892 - 882.1	8
	D	872 - 870	55
	K	877.4 - 865.9	117
	H	844 - 824.1	.4
	C	810 - 808	7
	J	817.4 - 805.9	.7
	G	800 - 780.1	.01
	B	768 - 765	.008
	A	755 - 744	.002
FL-801	K	873.5 - 861.8	19
	J	813.5 - 801.8	2
FL-802	K	874.5 - 863	55
	J	814.5 - 803	.7

able features indicated with the caliper and flowmeter logs were consistent with those intervals having high Kh from the slug tests.

Constant-discharge aquifer tests

The hydraulic connection among the three boreholes through specific intervals was evaluated by cross-borehole testing, where water was pumped from test intervals isolated with a packer assembly in one borehole and changes in water level were observed in the other two boreholes. Intervals J (the permeable bedding-plane parting at about 810 FANGVD29) and K (the permeable bedding-plane parting at about 870 FANGVD29) (fig. G6) were selected for cross-borehole testing based on evaluation of the cores, geophysical logs, and slug tests. Cross-borehole tests were conducted in intervals J and K independently. Interval J was pumped at about 4 gal/min in each borehole, while drawdown in the pumped borehole and both observation boreholes was monitored. Following the evaluation of interval J, the packers were moved to isolate interval K, which was evaluated in the same manner.

The results of the cross-hole aquifer test in interval J are presented in figures G7a, b, and c. Drawdown in the pumped borehole was greatest in borehole FL-800 at about 33 ft, and least in FL-801 at about 4.5 ft. These data indicate that test interval J is most permeable at borehole FL-801 and least permeable in borehole FL-800. During pumping from any of the three boreholes, drawdown began immediately in the others. Regardless of the magnitude of the drawdown in the pumped borehole, drawdown in interval J in the observation boreholes was about 1 ft at the end of the pumping phase of the test (100 minutes), indicating that the test interval is isotropic in the vicinity of the boreholes. The pumped borehole recovered more quickly than the observation boreholes during pumping in boreholes FL-800 and FL-801 (figs. G7a and b). Initially, the rate of recovery after the termination of pumping in borehole FL-802 was faster than in the other boreholes. Once the water level in borehole FL-802 equaled that of the other boreholes, the recovery data were similar for all three boreholes (fig. G7a).

The results of the cross-hole aquifer test in packed interval K are presented in figures G8a, b, and c. Drawdown in the pumped borehole was much less in interval K than observed in interval J, indicating that interval K is more permeable. The drawdown was greatest in borehole FL-801 (about 1.3 ft), and least in borehole FL-800 (about 0.9 ft). The drawdown values are similar, but the specific-capacity data indicate that test interval K may be most permeable at borehole FL-800 and least permeable in borehole FL-801. Pumping from any of the three boreholes results in immediate drawdown in the others. Regardless of the magnitude of the drawdown in the

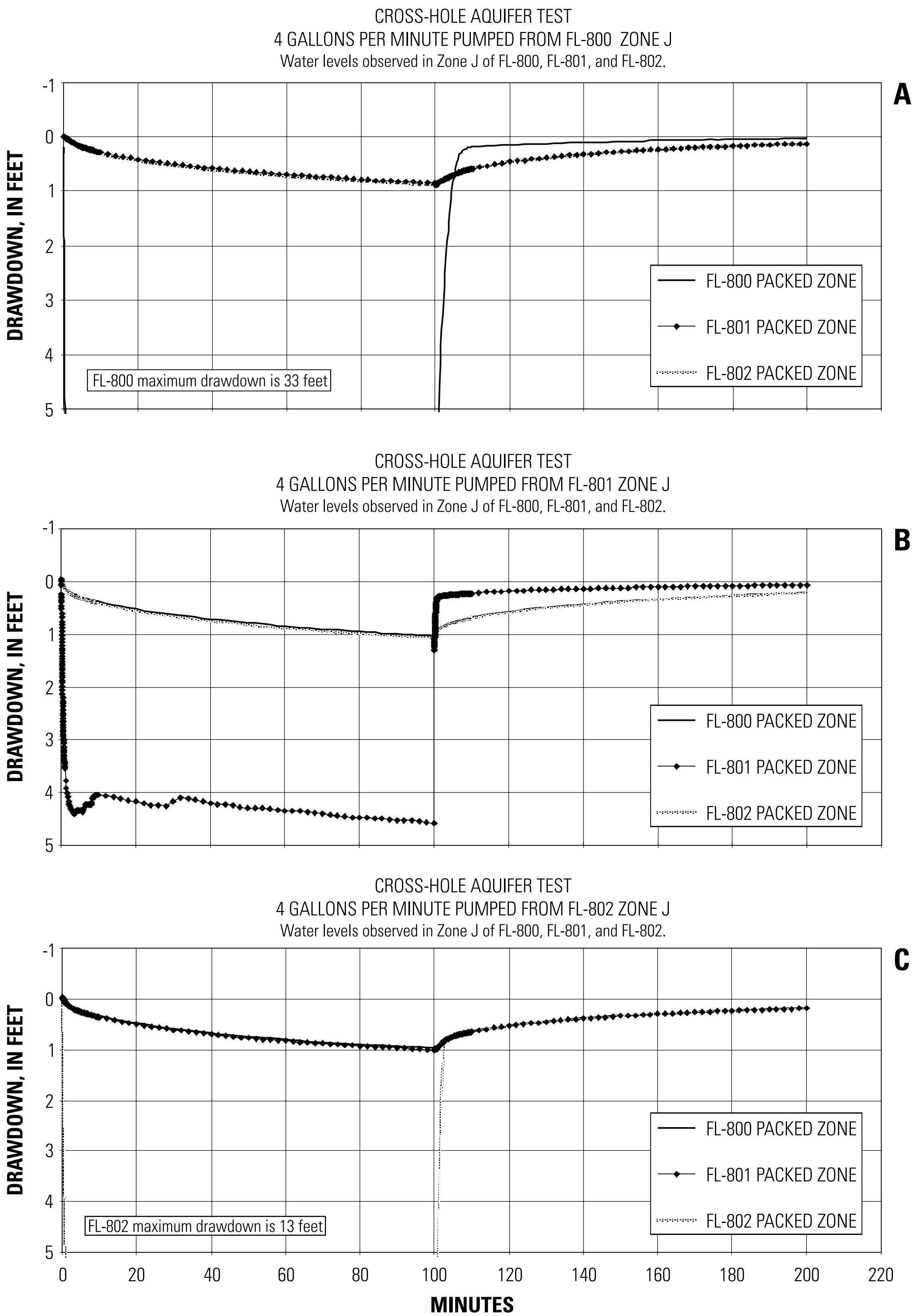

Figure G7. Changes in water levels observed in packed interval J during cross-borehole aquifer tests at the Waupun site, Wis. A) pumped borehole is FL-800, B) pumped borehole is FL-801, C) pumped borehole is FL-802.

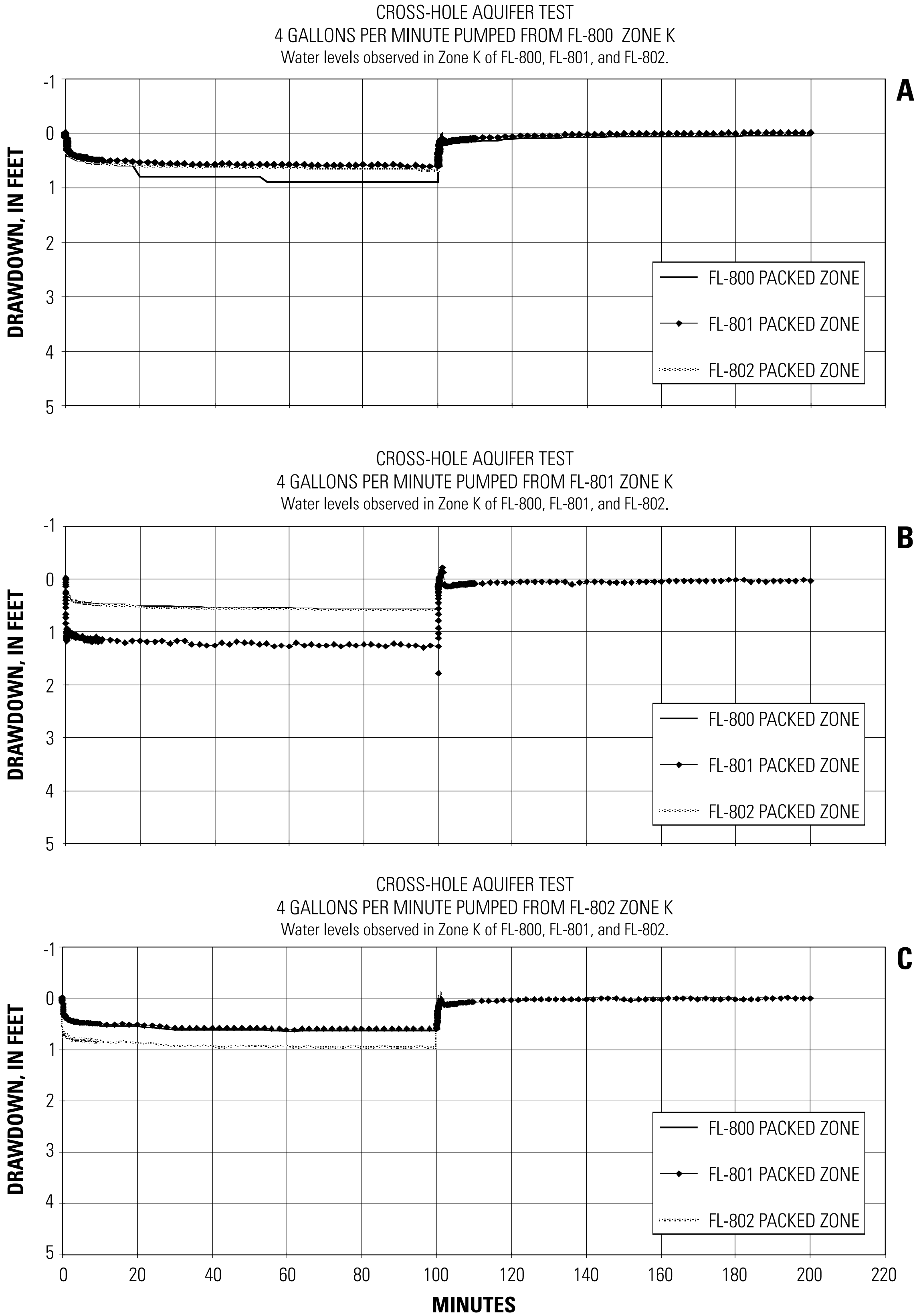

Figure G8. Changes in water levels observed in packed interval K during cross-borehole aquifer tests at the Waupun site, Wis. A) pumped borehole is FL-800, B) pumped borehole is FL-801, C) pumped borehole is FL-802.

pumped borehole, the drawdown in the other boreholes was between 0.6 and 0.7 ft at the end of the pumping phase of the test (100 minutes). Initially, the rate of recovery after the termination of pumping in the pumped boreholes was faster than in the observation boreholes. Once the water level in the pumped borehole equaled that of the observation boreholes, the recovery data were similar for all three boreholes (figs. G8a, b, c). All of the recovery profiles for test interval K showed water-level oscillation, which is indicative of a highly permeable aquifer.

Location of contaminants

Water-quality analyses were conducted only for samples from borehole FL-800. Samples were collected on April 8 and 9, 1996, during borehole development, and on April 24 and 25, 1996, from four test intervals isolated by use of a packer assembly. Test interval F was defined by a single packer set at 917 FANGVD29 with the tested interval extending to the water table at 930.5 FANGVD29 (fig. G6). Test intervals C, D, and E were isolated by two packers on either side of a 2-ft screen. Intervals C and D are shorter packed intervals that fall within intervals J and K, respectively (fig. G7). Analytical data for inorganic constituents and major ions are presented in tables G6 and G7.

In the samples taken during borehole development, acetone, trichloroethene, tetrachlorethene, 1,1,2-trichloroethane, and diethylphthalate were detected and considered representative of in-situ water quality. In the samples taken from the test intervals isolated by use of a packer assembly, 3-Heptone was detected in zone F. Acetone and toluene were detected in zone E. Trichloroethene was detected in zone D, and toluene was detected in zone C. Detections of VOC's are too sparse to assist in characterization of the secondary-permeability network at the Waupun site.

REFERENCES CITED

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Table G6. Inorganic and major ion analytical data for water from test intervals F, E, D, and C in borehole FL-800 sampled April 24 and 25, 1996, at the Waupun site, Fond du Lac County, Wis.

[MCL, maximum contaminant level; -, no established MCL; mg/L, milligrams per liter; µg/L, micrograms per liter; µSiemens/cm, microSiemens per centimeter; na, not analyzed; test interval reported as feet above National Geodetic Vertical Datum of 1929]

Constituent	MCL[a]	Units	Test interval F, from 917 to 930.5 feet	Test interval E, from 905 to 907 feet	Test interval D, from 870 to 872 feet	Test interval C, from 808 to 810 feet
pH	-	Standard units	7.67	7.4	7.4	7.2
Hardness Total	-	mg/L as $CaCo_3$	na	610	570	640
Calcium dissolved	-	mg/L as Ca	na	130	120	130
Magnesium dissolved	-	mg/L as Mg	na	70	66	76
Sodium dissolved	-	mg/L as Na	na	10	15	17
Sodium adsorption ratio	-	ratio	na	.2	.3	.3
Sodium percent	-	percent	na	4	6	6
Potassium dissolved	-	mg/L as K	na	5.5	15	31
Chloride dissolved	-	mg/L as Cl	190	81	95	130
Sulfate dissolved	-	mg/L as SO_4	110	120	140	150
Fluoride dissolved	-	mg/L as F	.1	.2	.2	.2
Silica dissolved	-	mg/L as SiO_2	19	15	13	14
Iron dissolved	300	µg/L as Fe	25	190	330	250
Manganese dissolved	50	µg/L as Mn	140	34	74	93
Residue dissolved 180C	-	mg/L	1080	700	692	884
Dissolved solids sum	-	mg/L	na	665	672	796
Bromide dissolved	-	mg/L as Br	.06	.1	.09	.11
Specific conductance	-	µSiemens/cm	1490	1110	1130	1400
Alkalinity as CaCO3	-	mg/L as $CaCo_3$	317	388	345	412

[a] Secondary Drinking Water Standard (U.S. Environmental Protection Agency, 2000)

Table G7. Trace element and major ion analytical data for water from test intervals F, E, D, and C in borehole FL-800 sampled April 24 and 25, 1996, at the Waupun site, Fond du Lac County, Wis.

[All values reported in micrograms per liter; MCL, maximum contaminant level; -, no established MCL; <, less than the indicated detection limit; (B), detected in laboratory blank; --, not analyzed; zone interval reported as feet above National Geodetic Vertical Datum of 1929]

Constituent	MCL	Test interval F, from 917 to 930.5 feet	Test interval E, from 905 to 907 feet	Test interval D, from 870 to 872 feet	Test interval C, from 808 to 810 feet
Aluminum	50-200 [b]	272	< 80	< 80	< 80
Antimony	6 [a]	1	2	21	9
Arsenic	50 [a]	< 2	4.1	5.1	< 2
Barium	2,000 [a]	208	175	209	216
Beryllium	4 [a]	< 1	< 1	< 1	< 1
Cadmium	5 [a]	< 0.2	< 0.2	< 0.2	< 0.2
Calcium	-	145,000	129,000	122,000	140,000
Chromium	100 [a]	< 8	< 8	< 8	< 8
Cobalt	-	< 6	< 6	< 6	< 6
Copper	1,000 [b]	48.7	43.2	< 6	< 6
Iron	300 [b]	778	456	775	432
Lead	15 [a]	5	< 2	2	< 4
Magnesium	-	87,900	68,000	65,200	77,100
Manganese	50 [b]	149	40.9	88.2	108
Nickel	100 [a]	33.8	74.4	37.4	35.2
Potassium	-	99,200	8780	18,700	36,900
Selenium	50 [a]	< 2	< 2	< 2	< 2
Silver	100 [b]	< 6	< 6	< 6	< 6
Sodium	20,000 [c]	25,400	10,700	15,500	18,000
Thallium	2 [a]	< 2	< 2	< 2	< 2
Vanadium	-	< 5	< 5	< 5	< 5
Zinc	5,000 [b]	43.6	< 40	56.4	307

[a] Primary Drinking Water Standard (U.S. Environmental Protection Agency, 2000)

[b] Secondary Drinking Water Standard (U.S. Environmental Protection Agency, 2000)

[c] Drinking Water Equivalent Level (U.S. Environmental Protection Agency, 2000)

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